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MONTE CARLO STUDY OF ASYMMETRY EFFECTS IN A LITHIUM OXIDE BLANKET FOR A LASER DRIVEN REACTOR

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ABSTRACT

Time-integrated neutronics and photonics scoping studies for a lithium oxide blanket developed for a laser driven fusion reactor are presented. Two dimensional Monte Carlo calculations have been used to assess the asymmetry effects resulting from the geometry of the reactor cavity as a right circular cylinder with two hemispherical caps. Such a shape is characteristic for laser fusion cavities designed to employ magnetic protection of the cavity liner or first wall. An average value for the tritium yield per source neutron is obtained as 1.1549, and an average total nuclear heating of 14.4904 Mev/D-T neutron. The tritium production, nuclear heating, atomic displacements and gas production rates are found to vary substantially in different regions of the blanket by as much as 300% for some parameters. The non-uniformity of these parameters in different regions of the blanket is expected to seriously affect the shielding, mechanical and heat transfer designs and will lead to varied components lifetimes.

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1. INTRODUCTION AND BACKGROUND

Two-dimensional neutronics and photonics calculations have been used in scoping studies to investigate the characteristics of a lithium oxide blanket for a laser induced fusion power reactor conceptual design[1]. The study surveys the effect of a suggested cylindrical shape reactor cavity with upper and lower hemispherical caps on energy generation, radiation attenuation, potential radiation damage, and tritium breeding. Such a shape with a point source at the center of the cavity may offer the possibilities of simple component design, easy lithium oxide particles flow and of magnetically protecting the first wall with an axial magnetic field, but may present a non-uniformity in heat generation, components lifetimes, nuclides breeding and shielding requirements. Since detailed flux distributions are not required for our scoping studies, Monte Carlo provides economical estimates of integrated quantities and is preferred to Discrete Ordinates.

The Lithium Oxide blanket concept has been previously treated by Sze et. al.[2], and Cheng et. al.[3]. Ragheb, Cheng and Conn[4] carried out a one-dimensional comparative Monte Carlo and Discrete Ordinates study for different blanket and shield calculations models for that same concept. Monte Carlo estimates of tritium breeding, neutron and gamma heating and neutron primary damage effects compared satisfactorily with the Discrete Ordinates results. The reliability of the used version of the Monte Carlo code[5] was established, as well as the competitiveness of Monte Carlo to Discrete Ordinates when integrated quantities are required in scoping studies and when moderate particle penetrations are involved. They recommended the use of Monte Carlo for further studies of laser fusion problems possessing a multidimensional nature: asymmetry effects (this work), penetrations for multiple laser beam ports, shielding of cryogenic fuel-pellet injection

and magnetic first wall protection systems, and of beam focusing, diverging, deflection and splitting components.

The neutronics and photonics for a laser induced fusion system is basically a time-dependent problem, and coupled pellet-blanket-shield neutronics and photonics studies may need to be adopted in more advanced stages of investigation. However, for a constant periodic microexplosion fusion reactor, time-integrated quantities such as the tritium breeding, total nuclear heating and gas production rates can be obtained using steady-state transport calculations[1,4], which is the case in the present work.

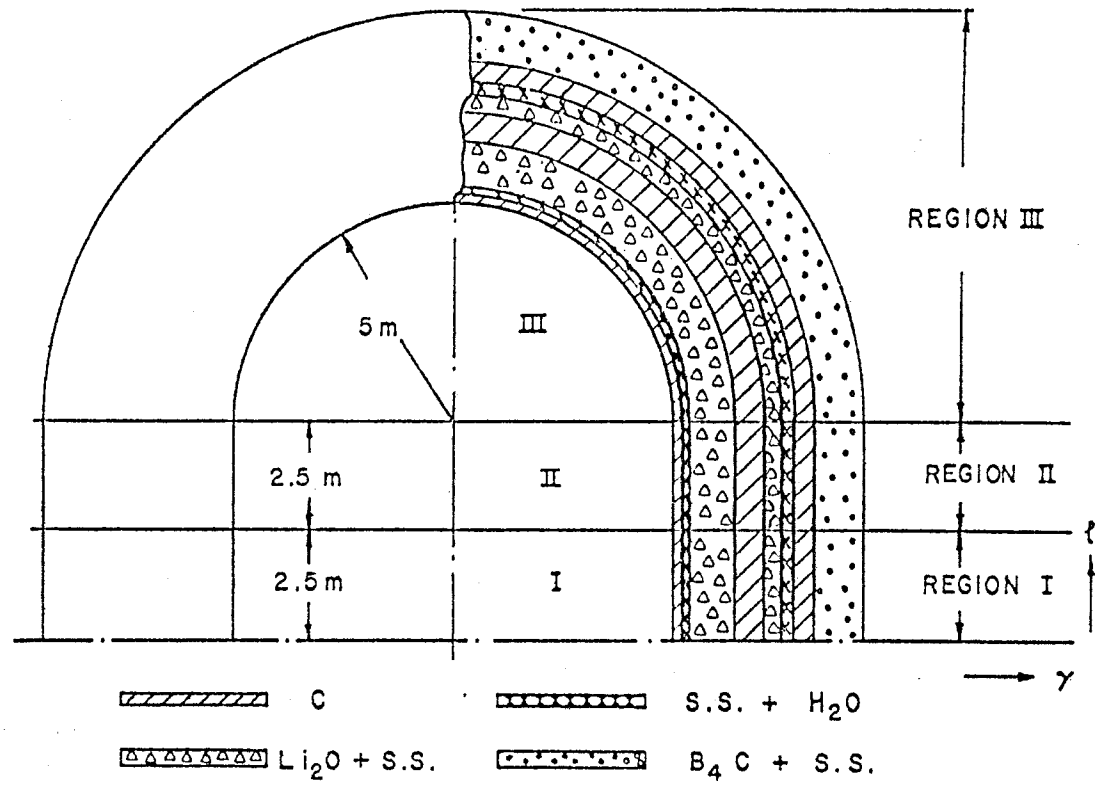
Liquid lithium has been frequently proposed as a breeding material and coolant for fusion reactors studies[8]. Helium gas under high pressure has also been proposed as the coolant to avoid MHD effects and the corrosion of structural materials ensued from the circulation of high temperature lithium[10]. High melting point solid compounds such as L_iAl, $LiAlO_2$, and Li_2O have been proposed as breeding materials. A molten lithium compound called Flibe ($L_iB_eF_3$) has been proposed also by Mills[9] et.al. Potassium vapor has been suggested as coolant for a high efficiency power cycle[10]. The presently treated lithium oxide blanket concept uses lithium oxide particles as the coolant and the breeding material for a laser fusion power reactor. This concept for laser reactors offers the following advantages: liquid lithium corrosion, tritium recovery and magneto hydrodynamic problems (if first wall is magnetically protected) are avoided, a low pressure blanket can be used instead of the high pressure helium coolant and its associated high circulation power requirement, no neutron multipliers such as the beryllium used in conjunction with L_iAl, $LiAlO_2$ and Flibe systems is needed, together with the freedom from the sintering problem met with in $LiAlO_2$ applications, and a low tritium mobility[2].

The principal effort in the present work is to aid in assessing the effect of the asymmetry of the treated geometry with regard to integrals of the neutron and gamma heating, the tritium breeding and primary neutron damage effects in different parts of the blanket. The study provides an estimate of the overall tritium production per source neutron of 1.1549 and an overall total nuclear heating by neutrons and gammas of 14.5 Mev per D-T neutron, as well as estimates for gas production and atomic displacement rates. The calculations reveal that the effect will cause non-uniformities in heating rates, tritium production and other nuclear parameter at different parts around the suggested geometry. This may lead to difficulties with respect to the heat transfer system design, and to components lifetimes, maintenance and replacement schedules; so that if mechanical design considerations allow it, and if the magnetic protection of the first wall may be avoided by alternative protection measures; recourse to a spherical geometry for the cavity may alleviate these problems.

In the following, the details of the blanket model and method of calculation and a discussion of the results are described.

2. DETAILS OF REACTOR MODEL AND METHOD OF CALCULATION

A schematic representation of the blanket and shield configuration for our laser reactor model is shown in Figure 1. Because of symmetry, the upper half of the cavity is shown as used in the calculations. Since a 6 beam-pellet illumination system is presently contemplated, a 120° sector above the midplane was considered, foreseeing a future computation including a beam penetration. The neutron source is a point isotropic source of 14 Mev neutrons at the center of the cavity. The cavity is divided into three regions: Regions I and II are of equal volume and represent the cylindrical part of the cavity, while region III represents the hemispherical portion.



TWO - DIMENSIONAL NEUTRONIC AND PHOTONIC CALCULATIONAL MODEL FOR THE Li_2O LASER FUSION REACTOR BLANKET

FIGURE 1

The Li_2O coolant normally flows downwards through an inlet part at the top of the hemisphere, but was not included in the present model. Each of the regions of the blanket is further divided into several zones (or subregions). The composition of these zones is shown in Table 1. Their volumes in the 120° sector analyzed are shown in Table 2 . Zone 1 includes the carbon liner and the vacuum separating the liner from the first wall and was modeled by a region of 2.5 cm thick graphite with a density factor of 0.3. Zone 2 represents the water-cooled first wall tubing and is simulated by a 2 cm zone of 24.4% stainless steel and 30.24% H_2O which corresponds to an average void fraction for the water of 60%. The cooling and breeding zones contain Li_2O particles (60% dense) and stainless steel structure (2%). Zone 3 is the main blanket and is 35 cm thick, while zone 5 is a scrape off region of only 6 cm thick. A graphite reflector of 15 cm thickness separates these two regions. Zone 6 is a 3.9 cm of steam cooled tubing. A second graphite zone 7, 10 cm thick, and a 40 cm zone 8 are included to account for the proper neutron reflection from the shield to the blanket as suggested in Reference 3. The shield design is not treated in our study but will be included at a later stage.

The neutronics and photonics calculations were performed by Monte Carlo using a modified version of the MORSE[5,6,7] multigroup code. The nuclear data information has been given in Reference 3, and consists of a collapsed set of 25 neutron and 21 gamma energy groups. Two cases of 1000 and 5000 histories were run, to check for the statistical convergence of the results. The 5000 histories case is considered adequate for our scoping studies purpose. The 5000 histories case required 110.22 minutes of UNIVAC-1110 CPU computing time and cost $249. The 1000 histories case required 22.13 minutes and cost $51, based on rates for weekend runs.

Table 1

Materials Compositions in the Blanket Model

Zone	Identification	Thickness (cm)	Composition
1	Carbon liner and vacuum region	2.5	Graphite 30% d.f.[a]
2	First Wall Tubing	2.0	24.4% S.S.[b] 75.6% H_2O [c]
3	Main Blanket	35.0	60% Li_2O + 2% S.S.
4	Primary Reflector	15.0	Graphite 100% d.f.
5	Scrapeoff region	6.0	60% Li_2O + 2% S.S.
6	Cooling region	3.9	35.6% S.S. + Steam
7	Secondary Reflector	10.0	Graphite 100% d.f.
8	Shield	40.0	90% B_4C + 10% S.S.

a) d.f. stands for density factor

b) S.S. stands for stainless steel

c) H_2O density corresponds to an average 60% void fraction

Table 2

Volumes of Zones in Different Regions

Zone No.	Volume† (cm^3)	
	Regions I and II	Region III
1	6.561347 + 05	1.315553 + 06
2	5.272640 + 05	1.061911 + 06
3	9.566150 + 06	1.998160 + 07
4	4.296128 + 06	9.400517 + 06
5	1.751438 + 06	3.905743 + 06
6	1.148543 + 06	2.584001 + 06
7	2.981371 + 06	6.790547 + 06
8	1.244908 + 07	2.961011 + 07

† These volumes correspond to a 120° sector of the half upper cavity. The projection of a future beam calculation, and a preliminary choice of a 6 beams particle illumination lead to that choice.

The neutron source in this work is the average number of neutrons released in the fusion microexplosion per second. The total energy released per second is assumed to be 3000 MJ, which corresponds to 1.0639×10^{21} neutrons/sec (17.6 Mev energy is released per fusion reaction). Computations of time integrated results were carried out using a source term of 1.06394×10^{21} (source neutrons/sec) to represent a laser event.

The collision estimator is used together with a combinatorial geometry package[4,5,6] to represent the geometry regions. Region detectors are used rather than point detectors to reduce the computation cost. Unit weights are assigned to the generated secondary particles in all groups and regions. Statistics are based on the batch (experiment) concept in the Monte calculation. Discussion of the obtained results follows in the next section.

3. DISCUSSION OF THE RESULTS

A summary of the neutronics and photonics calculations for 1000 and 5000 histories are presented in Table 3 and Table 4 respectively. The case of 1000 histories is included to show the statistical convergence of the result in the 5000 histories case, and to give an idea about the amount of information obtainable with such a small number of histories at a very economical cost. The results show Monte Carlo to be quite acceptable and useful for blanket scoping studies. The fractional standard deviation based on the 68% confidence interval is shown in parentheses as a percentage of the obtained estimates. It should be noticed that the confidence intervals in the 1000 histories for tritium production and nuclear heating are quite adequate for scoping studies. The 5000 histories case is needed to reduce the confidence intervals to acceptable size for the radiation damage parameters, namely, the atomic displacement, and gas (H and He) production rates. The reason is that we used the collision estimator which requires a large number of simulations

Table 3

Summary of Tritium Breeding, Nuclear Heating and Radiation Damage Parameters in the Laser Fusion Reactor Blanket

(P_3, 1000 Histories)

	Region I	Region II	Region III	Total (if applicable)
Tritium Breeding[a]				
T_6	0.2826 (5.0%)[e]	0.1690 (7.0%)	0.2716 (4.8%)	0.7232 (3.1%)
T_7	0.1783 (4.4%)	0.0925 (7.0%)	0.1369 (6.4%)	0.4077 (3.3%)
$T_6 + T_7$	0.4609 (3.5%)	0.2615 (5.8%)	0.4085 (3.8%)	1.1309 (2.3%)
Nuclear Heating[b]				
Neutron Heating	5.0266 (3.7%)	2.7096 (5.3%)	4.0430 (4.5%)	11.7792 (2.5%)
Gamma Heating	1.1248 (3.9%)	0.6572 (4.9%)	0.9205 (5.1%)	2.7025 (2.7%)
Total Heating	6.1514 (3.1%)	3.3668 (4.4%)	4.9635 (3.8%)	14.4817 (2.1%)
Radiation Damage Parameters to Carbon Liner				
Atomic Displacement[c]	31.97 (5.3%)	21.32 (23%)	14.15 (12%)	--
Helium Production[d]	11200 (17%)	5359 (21%)	4187 (17%)	--
Radiation Damage Parameters to Stainless Steel Wall				
Atomic Displacement[c]	33.97 (18%)	23.05 (17%)	10.17 (23%)	--
Helium Production[d]	871 (11%)	583 (14%)	186 (16%)	--
Hydrogen Production[d]	2664 (9.9%)	1764 (14%)	641 (14%)	--

(a) in units of t/D-T neutron
(b) in units of MeV per D-T neutron
(c) dpa/year
(d) appm/year
(e) (x%) represents the percent value for one standard deviation

Table 4

Summary of Tritium Breeding, Nuclear Heating and Radiation Damage Parameters in the Laser Fusion Reactor Blanket

(P_3, 5000 Histories)

	Region I	Region II	Region III	Total (if applicable)
Tritium Breeding[a]				
T_6	0.2619 (2.3%)[e]	0.1837 (2.4%)	0.2953 (1.1%)	0.7409 (1.2%)
T_7	0.1744 (2.3%)	0.1036 (2.8%)	0.1360 (2.9%)	0.4140 (1.5%)
$T_6 + T_7$	0.4363 (1.7%)	0.2873 (1.9%)	0.4313 (1.5%)	1.1549 (0.9%)
Nuclear Heating[b]				
Neutron Heating	4.6898 (1.7%)	2.9564 (1.9%)	4.1692 (1.7%)	11.8154 (1.0%)
Gamma Heating	1.0341 (1.8%)	0.6648 (2.5%)	0.9761 (1.7%)	2.6750 (1.1%)
Total Heating	5.7239 (1.4%)	3.6212 (1.6%)	5.1453 (1.4%)	14.4904 (0.8%)
Radiation Damage Parameters to Carbon Liner				
Atomic Displacement[c]	29.96 (8.7%)	20.15 (11%)	15.51 (7.9%)	------
Helium Production[d]	8910 (6.5%)	5584 (9.6%)	3569 (8.0%)	------
Radiation Damage Parameters to Stainless Steel Wall				
Atomic Displacement[c]	28.40 (9.5%)	19.34 (14%)	12.74 (10%)	------
Helium Production[d]	695 (5.3%)	471 (6.1%)	275 (6.4%)	------
Hydrogen Production[d]	2129 (4.7%)	1457 (5.8%)	870 (5.6%)	------

(a) in units of t/D-T neutron
(b) in units of MeV per D-T neutron
(c) dpa/year
(d) appm/year
(e) (x%) represents the percent value for one standard deviation

to score in optically thin regions such as the carbon liner and the first wall. The use of the track length estimator may prove better for estimation in these regions without recourse to an excessively large number of particle histories. We now discuss the results obtained for the different quantities of interest.

3.1 Tritium Breeding

Table 3 shows the results for tritium production per source neutron for the lithium-6 and lithium-7 components in regions I, II and III of the blanket model. As much tritium production occurs in the lower cylindrical part of the cavity as in the top hemisphere, even though they largely differ in size. The reason is that it is subjected to a higher particle wall loading by being closer to the geometric center of the cavity. A relative measure of the effectiveness of the different zones with respect to breeding can be obtained by defining the quantity:

$$\text{Zone breeding effectiveness} = \frac{\text{Tritium production per source neutron in zone}}{\text{volume of zone}}$$

This quantity is shown in Table 5. One notices that the breeding effectiveness decreases as we go from region I to II to III for both the Li-6 and Li-7 components in the main blanket and the scrapeoff zone. The scrapeoff zone in region I seems to be at least as effective in tritium breeding as the main blanket in region II, and more effective than the main blanket in region III. This suggests that the addition of a thicker stationary zone of lithium oxide before the shield around region I may contribute a significant amount to tritium production. The average value for tritium production of 1.1549 is satisfactory, but it would be advantageous to optimize the blanket to obtain a value around 1.2 to account for calculation and data uncertainties, and to accommodate expected losses during reactor operation in the heat transfer cycle, and during reprocessing.

Table 5

Zones Breeding - Effectiveness†

$N(Li^6)$ = 0.003 6507 atoms/(b. cm) , 1000 histories case

$N(Li^7)$ = 0.045 5493 atoms/(b. cm)

		Lithium-6 contribution	Lithium-7 contribution
Upper Hemisphere	Main Blanket	(1.258861-08) ± (0.061735-08)	(0.678489-08) ± (0.043254-08)
(Region III)	Scrapeoff Zone	(0.581038-08) ± (0.094930-08)	(0.033337-08) ± (0.014771-08)
Upper Cylindrical Shell	Main Blanket	(1.643133-08) ± (0.121773-08)	(0.959253-08) ± (0.068424-08)
(Region II)	Scrapeoff Zone	(0.673866-08) ± (0.105656-08)	(0.038945-08) ± (0.017076-08)
Lower Cylindrical Shell	Main Blanket	(2.589338-08) ± (0.134672-08)	(1.843704-08) ± (0.080607-08)
(Region I)	Scrapeoff Zone	(1.993938-08) ± (0.226691-08)	(0.110617-08) ± (0.051320-08)

† In units of tritium atoms/(source neutron·cm^3 of tritium producing region).
That quantity is a relative measure of the breeding capability of different zones in the geometry.

3.2 Neutron and Gamma Energy Deposition

Table 6 shows the nuclear energy deposition for neutrons and secondary gammas in different zones and regions of the blanket model in units of Mev/source neutron.

The non-uniformity in heat deposition from region to region for the same zone is apparent. Most of the heat deposition occurs in the Li_2O zone: 9.9 Mev/source neutron for neutrons and 1.79 Mev/source neutron for gammas; which amounts to 81% of the total energy deposition. Gamma heating amounts to 18% of the total heating of 14.4904 Mev/source neutron .

Table 7 shows the volumetric heating rates in units of Watts/cm^3. The highest volumetric heating rate over the system occurs in the first wall tubing and amounts to 12.91 Watts/cm^3, followed by that occurring in the main blanket (8.5 Watts/cm^3), then by the volumetric heating rate in the carbon liner. Figure 2 shows the volumetric heating rates in different regions and zones of the blanket. The non-uniformity is again apparent, the heating rate in region I is two to three times larger than in region III. The heat transfer and mechanical designs of the reactor must take this into account.

3.3 Radiation Damage Parameters

Parameters important for radiation damage are displayed in Tables 4 and 5 in different regions for the carbon liner and the stainless steel first wall. In the carbon liner, the atomic displacement rates in region I are about twice as much as in region III. In the stainless steel first wall and helium production the same effect occurs for the hydrogen production too. Since radiation damage determines the lifetimes of the different components, parts of the blanket in region I are expected to require more frequent maintenance and replacement than parts in regions II and III. This is not

Table 6

Nuclear Energy Deposition in the Li_2O Laser Fusion Reactor Blanket
(in units of MeV per D-T neutron)

Region	I			II			III			I + II + III		
Nuclear Heating	Neutron	Gamma	Total	Neutron	Gamma	Total	Neutron	Gamma	Total	Neutron	Gamma	Total
Zone 1	0.1181	0.0258	0.1439	0.0751	0.0175	0.0926	0.1024	0.0252	0.1276	0.2956	0.0685	0.3641
	(6.0%)	(9.1%)	(4.9%)	(8.5%)	(11%)	(7.2%)	(6.5%)	(7.2%)	(5.4%)	(3.9%)	(5.2%)	(3.3%)
Zone 2	0.2593	0.1129	0.3722	0.1754	0.0749	0.2503	0.2334	0.1157	0.3391	0.6581	0.3035	0.9616
	(4.2%)	(5.3%)	(3.3%)	(5.3%)	(6.2%)	(4.2%)	(4.7%)	(4.2%)	(3.4%)	(2.7%)	(3.0%)	(2.1%)
Zone 3	3.9001	0.6902	4.5903	2.4747	0.4548	2.9295	3.5324	0.6461	4.1785	9.9072	1.7911	11.6983
	(2.0%)	(2.4%)	(1.7%)	(2.2%)	(3.4%)	(1.9%)	(1.9%)	(2.2%)	(1.6%)	(1.2%)	(1.5%)	(1.0%)
Zone 4	0.2054	0.1210	0.3264	0.1118	0.0695	0.1813	0.1438	0.1133	0.2571	0.4610	0.3038	0.7648
	(6.5%)	(5.0%)	(4.5%)	(7.1%)	(5.3%)	(4.8%)	(7.2%)	(4.3%)	(4.5%)	(4.0%)	(2.8%)	(2.7%)
Zone 5	0.1741	0.0238	0.1979	0.1027	0.0158	0.1185	0.1435	0.0216	0.1651	0.4203	0.0612	0.4815
	(5.7%)	(8.7%)	(5.2%)	(8.8%)	(10%)	(7.7%)	(6.4%)	(8.5%)	(5.7%)	(3.9%)	(5.2%)	(3.5%)
Zone 6	0.0050	0.0336	0.0386	0.0016	0.0193	0.0209	0.0034	0.0337	0.0371	0.0100	0.0866	0.0966
	(19%)	(7.2%)	(6.7%)	(26%)	(9.5%)	(9.0%)	(26%)	(11%)	(10%)	(14%)	(5.5%)	(5.1%)
Zone 7	0.0278	0.0268	0.0546	0.0151	0.0130	0.0281	0.0203	0.0205	0.0408	0.0632	0.0603	0.1235
	(13%)	(9.0%)	(8.0%)	(17%)	(11%)	(11%)	(17%)	(8.6%)	(7.0%)	(8.9%)	(5.5%)	(5.3%)
Summation over the Blanket	4.6898	1.0341	5.7239	2.9564	0.6648	3.6212	4.1692	0.9761	5.1453	11.8154	2.6750	14.4904
	(1.7%)	(1.8%)	(1.4%)	(1.9%)	(2.5%)	(1.6%)	(1.7%)	(1.7%)	(1.4%)	(1.0%)	(1.1%)	(0.8%)

Table 7

Average Nuclear Heating Rates in Each Region for Li_2O Blanket[a]

(Fusion Energy Produced Per Second = 3000 MJ)

Zone No.	Material Composition	Region I	Region II	Region III	Average Over System (I + II + III)
1	Carbon Liner	6.23 (4.9%)	4.01 (7.2%)	2.76 (5.4%)	3.94 (3.3%)
2	S.S. (24.4%) + H_2O (30.24%)	20.05 (3.3%)	13.49 (4.2%)	7.17 (3.4%)	12.91 (2.1%)
3	Li_2O (60%) + S.S. (2%)	13.63 (1.7%)	8.70 (1.9%)	5.94 (1.6%)	8.50 (1.0%)
4	Graphite	2.16 (4.5%)	1.20 (4.8%)	0.780 (4.5%)	1.21 (2.7%)
5	Li_2O (60%) + S.S. (2%)	3.21 (5.2%)	1.92 (7.7%)	1.20 (5.7%)	1.85 (3.5%)
6	S.S. (35.6%)	0.955 (6.7%)	0.517 (9.0%)	0.408 (10%)	0.562 (5.1%)
7	Graphite	0.520 (8.0%)	0.268 (11%)	0.171 (7.0%)	0.275 (5.3%)

a. in units of watt/cm^3

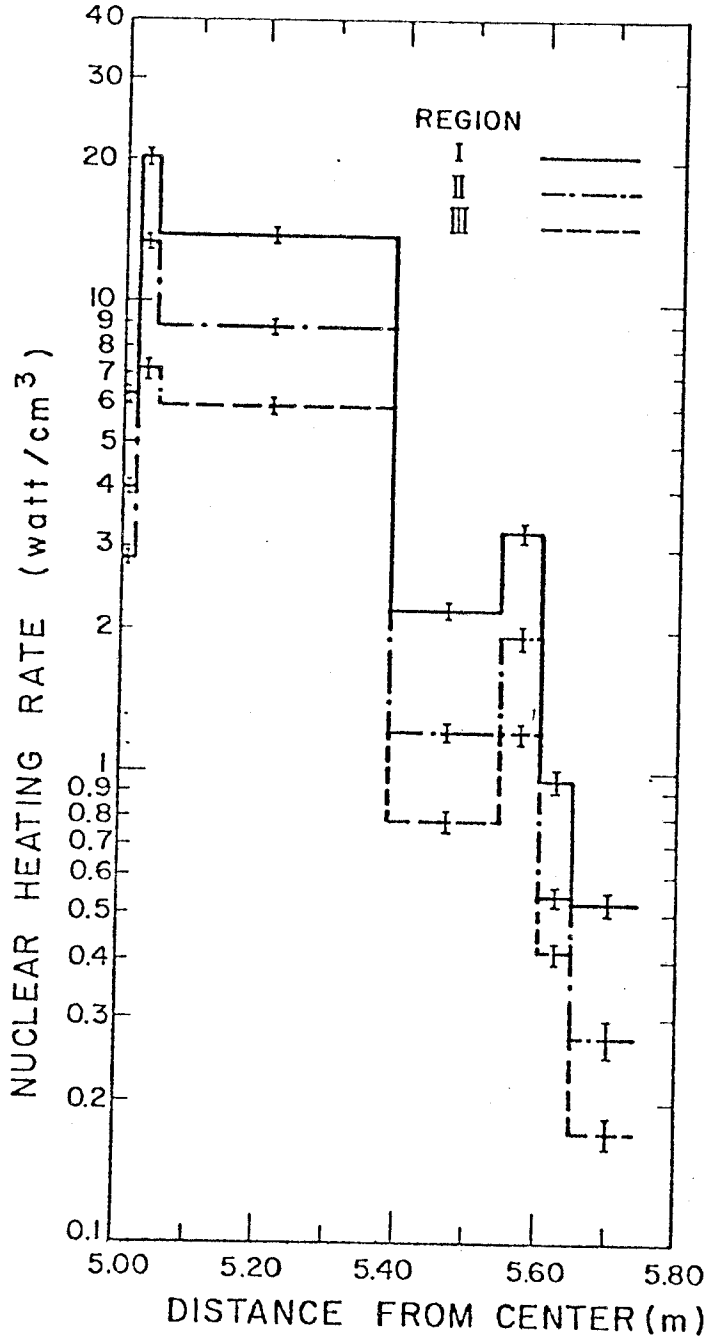

REGION
I
II
III
NUCLEAR HEATING RATE (watt/cm³)
40
30
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5.00
5.20
5.40
5.60
5.80
DISTANCE FROM CENTER (m)

FIGURE 2

a desirable feature and can be avoided by considering a spherical cavity in which the first wall and the graphite liner will be uniformly irradiated and will require complete, rather than partial replacement at specified reactor maintenance periods. We must remember, however, that the cylindrical shape was suggested by the possible use of an axial magnetic field to protect the first wall from charged particle pellet debris. Recourse to a spherical geometry can be done based on a thorough investigation of cavity size, first wall lifetime, alternate methods of protecting against charged particles, and blanket and shield size, weight and cost considerations.

3.4 Neutron and Gamma Spectra

Figures 3 and 4 display the neutron and gamma scalar fluxes in different regions and zones of the blanket model. An almost constant ratio exists between values in regions I, II and III in the different zones, which suggests that a detailed design can be carried out for region I, and then different parameter values can be deduced by extrapolation around the rest of the blanket using the displayed histograms. A detailed two dimensional calculation can thus be avoided.

The neutron and gamma spectra as a function of energy behave basically in the same fashion in the blanket regions. The neutron spectra in the zones of the upper hemisphere are shown in Figure 5. A crossover occurs for neutron spectra in the carbon reflector and Li_2O blanket. The slow neutrons spectrum is higher in the carbon reflector than in the blanket. But in the fast part, the opposite occurs, with the crossover occurring around one kev. Figure 6 shows the neutron spectra in one single zone (the Li oxide blanket), but in the three different regions. A definite ratio for the magnitude from region to region is apparent. The same effect occurs for the gamma spectra as shown in Figure 7. The gamma ray

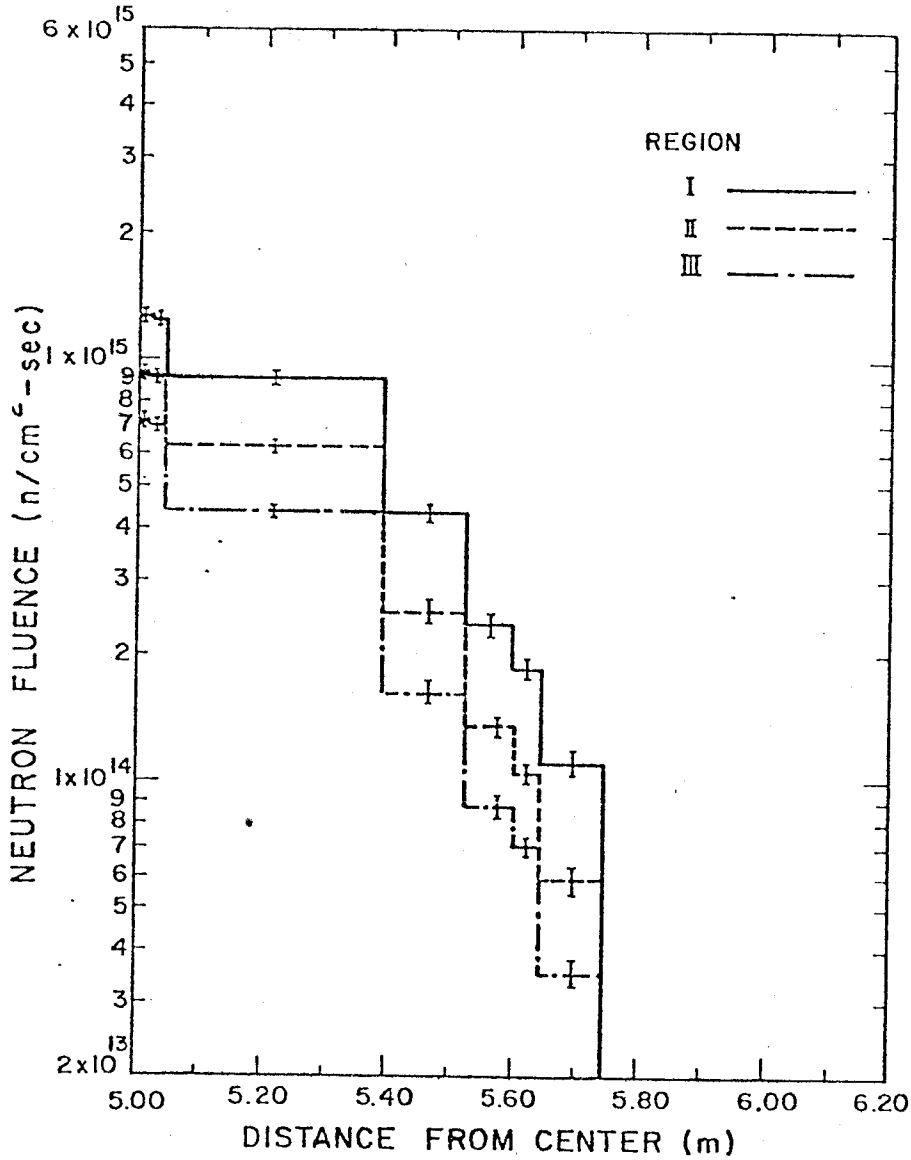

REGION
I
II
III
NEUTRON FLUENCE (n/cm²-sec)
6 x 10^15
1 x 10^15
1x10^14
2x10^13
5.00
5.20
5.40
5.60
5.80
6.00
6.20
DISTANCE FROM CENTER (m)

FIGURE 3

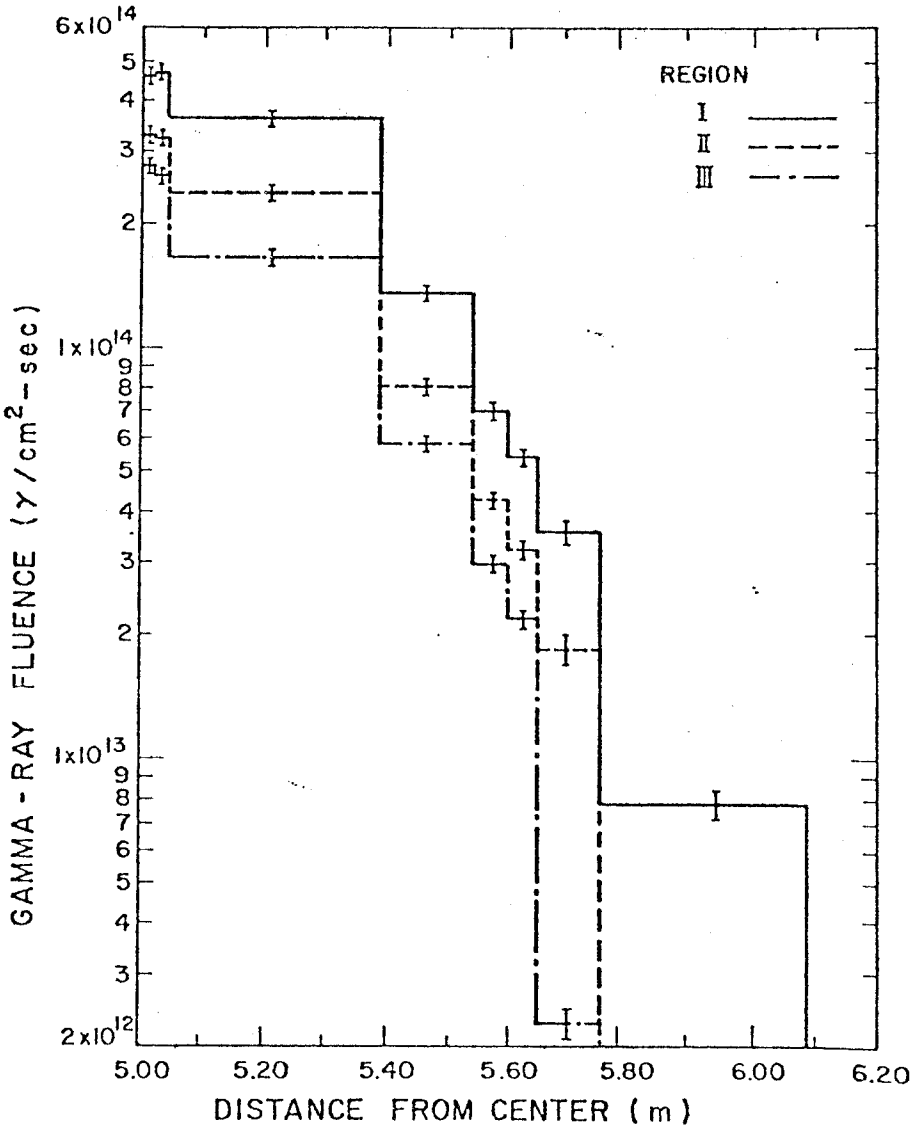

REGION
I
II
III
GAMMA - RAY FLUENCE (γ/cm²-sec)
6x10¹⁴
1x10¹⁴
1x10¹³
2x10¹²
5.00
5.20
5.40
5.60
5.80
6.00
6.20
DISTANCE FROM CENTER (m)

FIGURE 4

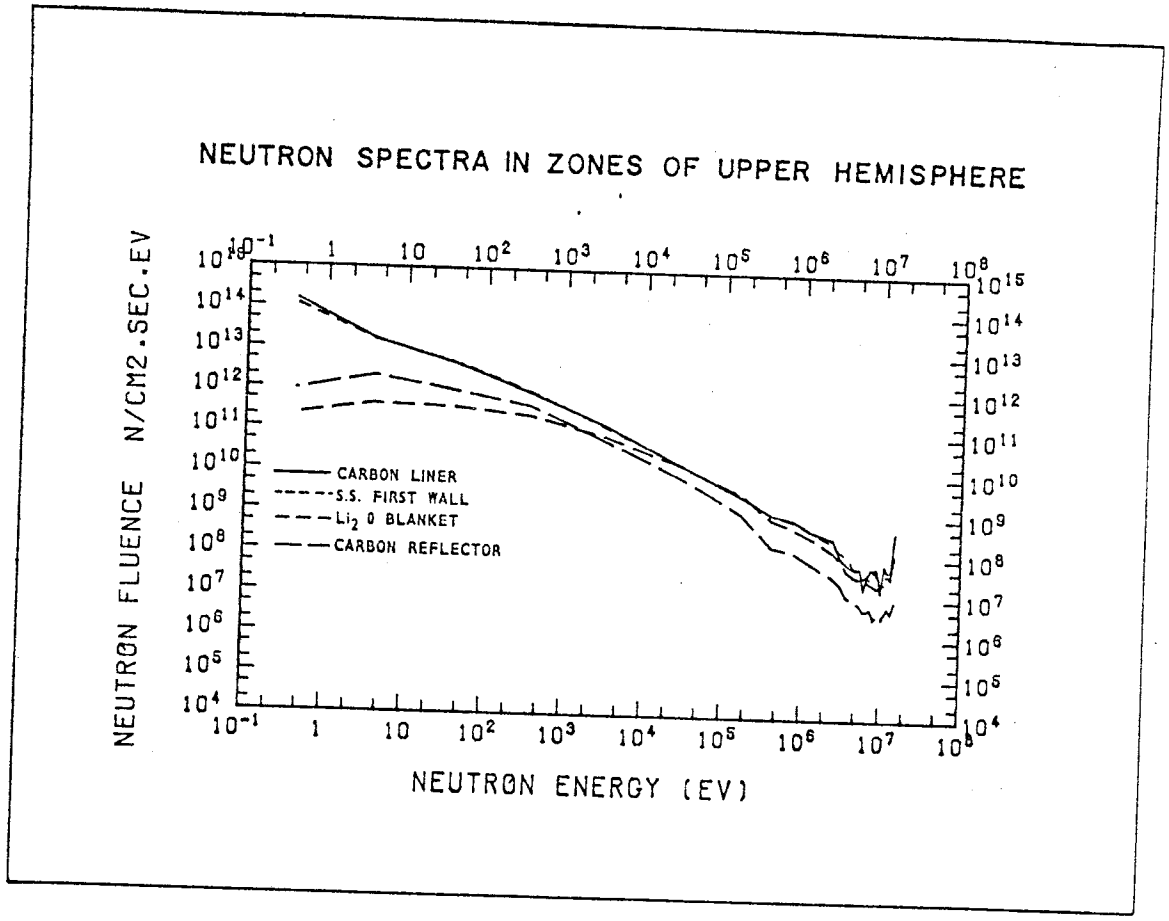

NEUTRON SPECTRA IN ZONES OF UPPER HEMISPHERE
NEUTRON FLUENCE N/CM2.SEC.EV
NEUTRON ENERGY (EV)
CARBON LINER
S.S. FIRST WALL
Li2 O BLANKET
CARBON REFLECTOR

FIGURE 5

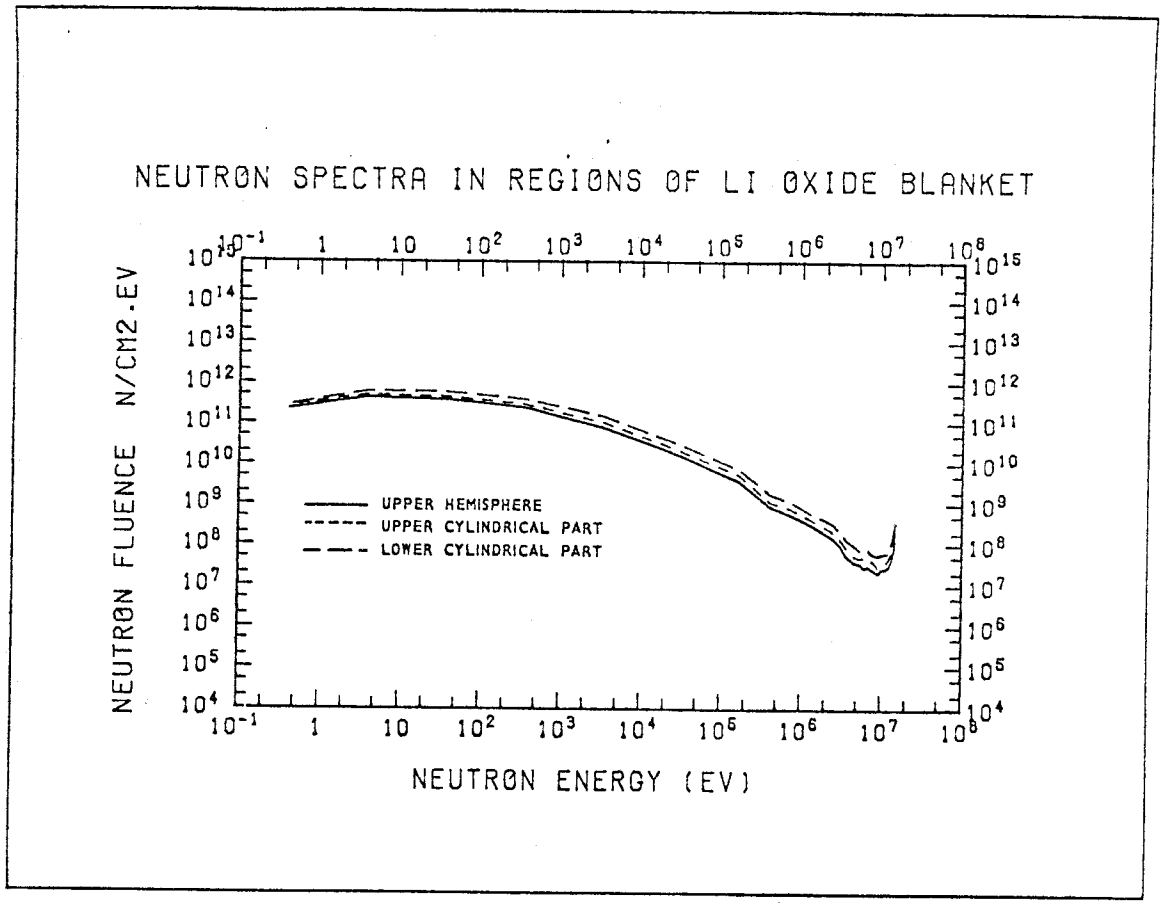

NEUTRON SPECTRA IN REGIONS OF LI OXIDE BLANKET
NEUTRON FLUENCE N/CM2.EV
NEUTRON ENERGY (EV)
UPPER HEMISPHERE
UPPER CYLINDRICAL PART
LOWER CYLINDRICAL PART

FIGURE 6

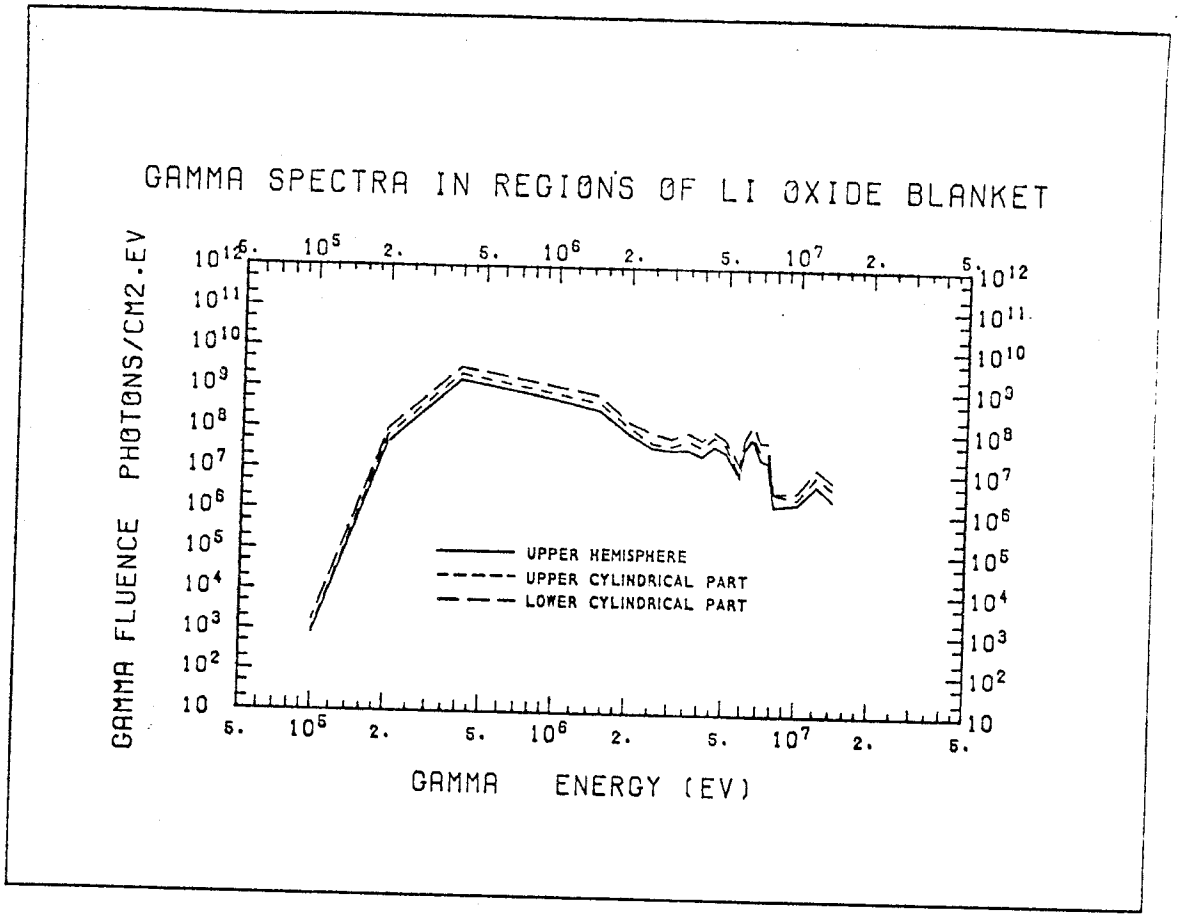

GAMMA SPECTRA IN REGIONS OF LI OXIDE BLANKET
GAMMA FLUENCE PHOTONS/CM2.EV
GAMMA ENERGY (EV)
UPPER HEMISPHERE
UPPER CYLINDRICAL PART
LOWER CYLINDRICAL PART

FIGURE 7

spectrum peaks around photons of 0.5 Mev, which must be accounted for in the shield design.

4. CONCLUSIONS AND RECOMMENDATIONS

Asymmetry effects in a cylindrical laser fusion cavity with two hemispherical end caps has been studied by two-dimensional Monte Carlo. The total tritium production per source neutron is 1.1549. The blanket may be optimized to raise this value to around 1.2. The main contribution to the breeding comes from the cylindrical portion of the treated Li oxide blanket. The total nuclear heating in 14.5 Mev per D-T neutron and 18% of this is due to gamma heating. Non-uniformities in heating rate, tritium production, atomic displacement and gas production rates in different parts of the blanket are revealed. This may lead to difficulties with respect to the mechanical and heat transfer designs, and to components lifetimes, maintenance and replacement schedules. If the magnetic protection of first wall, (which suggested the cylindrical cavity shape) can be avoided by alternative protection measures, recourse to a spherical geometry for the cavity will be most advantageous. Otherwise, further detailed two-dimensional studies will be necessary. Incorporation of laser beam penetrations and the estimation of radiation leakage, heating, and damage to the optical components will be considered in future investigations.

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